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BACTERIA IN MILK.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., February 3, 1912.

SIR: I have the honor to transmit for publication the manuscript of a revision of Farmers' Bulletin 348, "Bacteria in Milk," by Mr. L. A. Rogers, of the Dairy Division of this bureau. This paper in its original form appeared in the Yearbook of the Department for 1907 and was later issued as a Farmers' Bulletin. This revised edition is designed to supersede the old bulletin and it therefore should be published under a new number.

Respectfully,

A. D. MELVIN,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

[A list giving the titles of all Farmers' Bulletins available for distribution will be sent free upon application to a Member of Congress or the Secretary of Agriculture.]

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BACTERIA IN MILK.

MILK—ITS COMPOSITION AND CHARACTERISTICS.

A study of the changes produced in milk by bacteria is a study of the decomposition of the constituents of milk. Many of these changes are so complex that they can not be discussed in a paper of this nature. The fats are usually little affected by the growth of bacteria in milk. The sugar, on the other hand, is frequently fermented, and various acids, gases, and alcohol may result. The casein and the albumin are decomposed by many bacteria. The products of the decomposition sometimes have sharp or disagreeable flavors and not infrequently unpleasant odors.

It has been shown that milk contains certain digestive principles—the so-called unorganized ferments, or more properly enzyms—which slowly digest the milk. Fresh milk, collected and held without bacterial contamination, will spoil in time unless these enzyms are destroyed by heating.

BACTERIA—THEIR NATURE.

To understand the changes that take place in milk it is necessary to consider briefly the nature of the minute organisms causing these changes.

The basis of all life is the mysterious jellylike substance to which scientists have give the name of protoplasm. In its various forms it constitutes the actual living, changing part of every living thing, plant or animal. The simplest living things are merely shapeless, naked masses of this protoplasmic jelly. Bacteria show the first differentiation toward the complete plants with which we are familiar. The protoplasm is covered and held in definite shape by a very thin and delicate wall. They are then tiny one-celled plants. The plants growing in our gardens are made up of an infinite number of cells, organized like the workers in a community, each kind doing a particular work and all necessary to the complete plant. In bacteria, however, each cell is a complete plant in itself. (See figs. 1–4.) Their food must be in a condition to pass through the cell wall to the living protoplasm within. It must be in solution in water and it must

be diffusible—that is, it must be a substance that will pass through a membrane, otherwise it could not pass through the cell wall of the plant. Not all substances soluble in water will pass through a membrane. Thus albumin, while soluble, can not, as will be pointed out later, be used by bacteria until it has been changed.

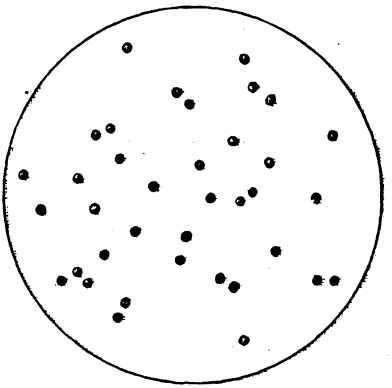

FIG 1.—Bacteria of the spherical or coccus type.

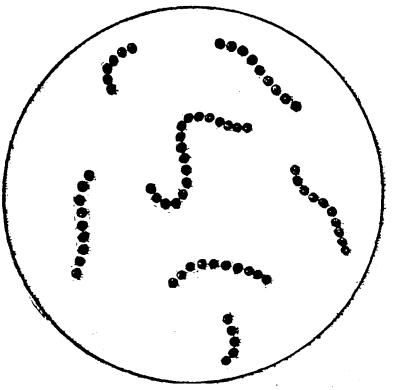

FIG. 2.—Bacteria of the coccus type hanging together in chains.

On the other hand, sugar is both soluble and diffusible and probably can be used for food by bacteria without previous change.

Through infinite generations of dependent existence bacteria have lost their ability to live independently and have become parasites or saprophytes. In other words, they are no longer able to elaborate

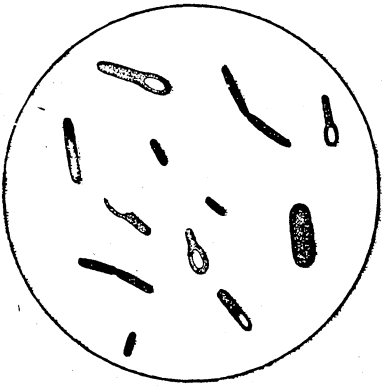

FIG. 3.—Typical rod-shaped bacteria (bacillus type). In some of these spores are shown as clear areas.

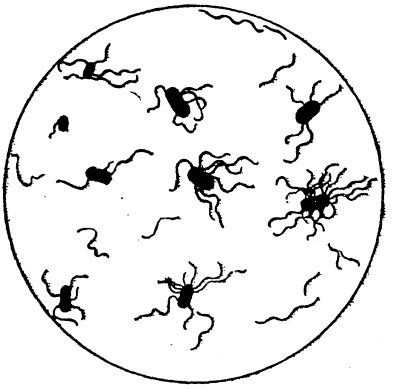

FIG. 4.—Bacteria with hairlike appendages which enable them to swim about in water or milk.

their nourishment from the simpler compounds existing in the air and the earth, but must depend on higher, better organized plants or animals to prepare their food for them. Hence we find them living only where there are present at least traces of animal or plant tissue. If they depend on living tissue, they are called parasites; if they

obtain their nourishment from dead, partly decomposed plant or animal matter, they are known as saprophytes.

The growing corn plant is so delicate that it is killed by a short exposure to a freezing temperature or to a scorching sun; yet the dried corn kernel will stand the most intense cold, long drying, or comparatively high heat, and when proper conditions are provided will grow. In a somewhat similar way some bacteria are provided with means of withstanding unfavorable conditions. These bacteria form a small round or oval body in the interior of the cell. When the bacterium dies, this spore, as it is called, is set free. Like the seeds of the higher plants, it is able to survive long drying and great extremes of temperature. To destroy spores by heat, it is necessary to expose them to long-continued boiling or for a short time to temperatures above the boiling point of water.

The bacteria are so small that it is difficult to form a conception of their dimensions. It is only when we consider them in the aggregate that they reach units of measure with which we are familiar. It is estimated that if 25,000 averaged-sized rod-shaped bacteria were placed end to end their combined length would equal 1 inch. The weight of an average bacillus is so small that it has been estimated to would take over 600,000,000,000 of them to equal 1 gram or 16,800,000,000,000 to weigh 1 ounce.

What the bacteria lack in size is made up in their great numbers and powers of reproduction. A cubic centimeter of milk, which contains about 25 drops, frequently contains thousands, sometimes millions, even hundreds of millions, of bacteria. A single drop of sour milk may contain 40,000,000 bacteria.

Bacteria reproduce themselves by a very simple process, known as fission. The cell becomes elongated and a partition wall is formed across the middle. The two cells thus formed separate, and we have two bacteria. Higher plants may take weeks and months, or even many years, to grow to maturity. These simple plants known as bacteria, however, under favorable conditions may complete their growth and reproduce themselves in less than an hour.

Bacteria, in common with all other living things, obey certain fixed laws. Certain elements and certain combinations of elements are necessary for their growth. There seem sometimes to be exceptions to these laws, but closer study shows that these exceptions are only apparent.

It would be very easy for the layman to obtain the impression by reading popular descriptions that bacteria are peculiar and unusual plants, having little in common with other forms of plant life. On the contrary, bacteria, in their form, habits of growth, and life processes, closely resemble many other simple plants, like the algæ, the yeasts, and the molds.

RELATION OF TEMPERATURE TO GROWTH OF BACTERIA.

The relation of bacteria to temperature is most interesting and important. A certain amount of heat is essential and a certain amount is fatal. Each particular variety of bacteria has an upper and a lower temperature limit beyond which it does not grow and a certain temperature, called the optimum, at which it grows best.

Most forms occurring in milk find their optimum temperature between 80° and 100° F. At a few degrees above 100 many forms will not grow at all and if the temperature is increased a point is soon reached at which only exceptional kinds will grow. At 125° the weaker cells of the ordinary forms soon die, but there are some varieties which occur in milk that grow readily at this temperature. An exposure of 10 minutes at 150° to 160° F. is fatal to a large part of the bacteria that do not form spores. However, the point at which they are destroyed by heat varies greatly, and many vegetative bacteria survive 150° F.

Spores, as previously mentioned, are destroyed only by prolonged boiling, exposure to steam under pressure, or to a high degree of dry heat. With dry heat, such as is obtained in an oven, much higher temperature and longer exposures are necessary to secure the same results. In the laboratory small flasks of milk are sterilized by holding them in a small steam boiler at a temperature of 248° F. for 15 minutes.

If the milk is cooled and held at 50° F. or, better still, 40°, growth is checked at once and multiplication is very slow. One writer has represented the relative increase of bacteria in milk held at different temperatures as follows:

Multiplicaton of bacteria in milk held at different temperatures.

Milk held at—	Relative number of bacteria at the end of—				
	0 hour.	6 hours.	12 hours.	24 hours.	48 hours.
68° F.	1	1.7	24.2	6,128.0	357,499.0
50° F.	1	1.2	1.5	4.1	6.2

In the foregoing table, 1 is assumed to represent the number of bacteria in the fresh milk, and the relative numbers which will be found at the end of 6, 12, 24, and 48 hours, at the two temperatures, are shown in the succeeding columns. These figures are based on a number of actual counts and illustrate the effect of a difference of 18° on the multiplication of bacteria. If the milk had contained at the beginning 1,000 bacteria, the part held at the lower temperature would have contained at the end of 24 hours only 4,100 bacteria,

while the other would have contained at the same stage 6,128,000. If the temperature is lowered below 40°, the growth is very much retarded and at the freezing point it ceases entirely for a short time at least. If milk is held at 32°, or even a few degrees lower, it does not form a solid piece of ice, but the water slowly forms into crystals and the milk remains in a semifluid condition. After a few days some of the bacteria begin to grow again and after a time may attain enormous numbers. These bacteria are not the ordinary kind, and they may cause marked changes in the chemical character of the milk without appreciably changing its appearance. It is therefore unsafe to assume that milk held for several days at a low temperature is safe because it looks all right.

The temperature may have a decided influence on the kind of bacteria growing in milk as well as on the numbers. There is a constant struggle for existence among the various kinds of bacteria in the milk, and those which find the conditions most favorable or succeed in so changing the milk that it is more favorable or less unfavorable to them than to other kinds will gradually crowd the others out. If a sample of milk is divided into three parts and held at three different temperatures—as, for instance, 35°, 70°, and 98°—the bacteria predominating in each of these parts at the end of two or three days will probably be quite different. Thus we see how it is that milk may undergo so many changes. Even when milk is handled in the same way day after day there may be marked differences in its appearance or flavor. Changes in the conditions so slight that they may escape our notice may produce great variation in the final results. The amount and nature of the contamination must necessarily vary more or less from day to day. Even with the same contamination the temperature of the atmosphere may change the whole course of the fermentation.

SOURCES OF BACTERIA IN MILK.

It has been assumed by many writers that milk is formed in the udder entirely free from bacteria. This has frequently been disputed and is still a matter of some doubt. However, the best authorities agree that milk is bacteria-free when formed, unless the udder is so injured or diseased that there is a direct passageway from the blood vessels to the milk ducts. It should be remembered that an injury so slight that it would escape the most careful examination might be sufficient to allow the passage of bacteria.

Even if the milk is secreted bacteria-free, it is very difficult to obtain it perfectly sterile. Bacteria work their way into the milk cistern through the opening in the teat and find there conditions

under which they can grow and multiply. This growth is ordinarily confined to the lower part of the udder, and the greater number of the bacteria are washed out with the first few streams of milk. Sometimes, however, the growth may extend into the smaller milk ducts, and the last part of the milk will contain nearly as many bacteria as the first.

Inflammation of the udder or fermentation of the milk in the udder rarely occurs, because there is only a very small amount of milk held in the udder, and most of the bacteria found there have little or no effect on milk. It is also true that fresh milk, like the blood, contains some substance which has an inhibiting influence on bacteria. This influence is so slight that it is probably of little practical importance, but it may have some relation to the comparatively slow development of bacteria in the udder.

The real contamination occurs after the milk has left the udder. In spite of careful milking, dirt, particles of dust, hairs, even bits of manure from the flanks or udder of the cow, may fall into the milk. All of these things invariably carry more or less bacterial contamination. Manure usually contains large numbers of bacteria, many of them being kinds which produce very undesirable changes in milk; and the dry dust of the stable floor contains great numbers and varieties of bacteria. This dust soon settles, and an open milk pail catches a surprisingly large amount.

But the contamination does not end here. The pails or the cans may not be properly cleaned, and the corners or seams may hold small particles of dirt or sour milk. These impurities are full of bacteria, which quickly find their way into the milk. The cloth through which the milk is strained may not have been properly scalded, and the bacteria are not only not all destroyed, but have actually multiplied in the damp cloth. When the strainer is used again many of these bacteria are washed out by the milk.

If a cooler is used it may add to the contamination if it is placed so that it catches dust. Finally, the bottles in which the milk is distributed may not have been properly washed and steamed, and thus may become another source of contamination.

The contamination from each individual source may be small, but taken all together it has a serious influence on the quality of the milk. If extraordinary precautions are taken to prevent contamination, the number of bacteria in the fresh milk may be kept down to a few hundred per cubic centimeter; with careful milking it may easily be kept within a few thousand; with careless milking and handling the number will vary greatly with circumstances and may exceed 100,000.

The bacteria in milk from cows kept in stables may be different from the bacteria in milk from cows on pasture. Bacteria which occur rarely in milk during the winter months may become numerous in the summer, and specific fermentations which are almost unknown in the summer may appear in the autumn or winter.

It should not be assumed that all bacteria are harmful either to milk or to the human system. In fact, many kinds of bacteria will grow in milk for a long time without changing its taste or appearance, while many of the fermentations which make milk undesirable for direct consumption are used in making butter and various kinds of cheese. Very few of the bacteria cause disease or produce poisonous by-products.

FLAVORS IN MILK.

Milk may acquire abnormal flavors and odors in various ways:

(1) The cow may, through some pathological condition, produce milk with an unusual flavor. This may occur when the cow shows no outward sign of disorder and usually lasts for a short time only.

(2) Highly flavored foods may impart their peculiar flavors to the milk. The disagreeable results of feeding even small quantities of wild onion, turnips, and similar feeds are unfortunately too familiar to need comment. Other feeds with a less pungent taste no doubt affect the flavor of the milk to a less degree.

(3) Milk, especially warm milk, takes up the odors and flavors of the surrounding air with great rapidity. The flavor thus acquired may be so slight that it ordinarily passes unnoticed, or it may be so pronounced that anyone may recognize its source.

(4) The flavor of milk may be materially changed by the growth of bacteria, with the infinite variety of by-products which result from their development. If milk is sterilized and then inoculated with some one kind of bacteria, a certain flavor, frequently very pronounced, will result; and under the same conditions this particular variety will always produce the same flavor. Another kind may produce an equally pronounced but entirely different flavor, while some species may grow for a long time without causing any noticeable change. In ordinary milk, however, the conditions are different, in that many kinds of bacteria are growing together and the milk is usually consumed before there is any marked change in the flavor.

When a number of different kinds of bacteria grow together, as they usually do in milk, the development is not equal. One variety finds the conditions of food or temperature or acidity more suited to its peculiar habits of life and develops more rapidly than other kinds. In a short time this rapidly growing form may so change the milk that, while the conditions are more favorable to its own growth, they become less and less adapted to the needs of the others. In the course

of time this form crowds out all others, and an examination would show large numbers of this kind, while the others originally present would have entirely disappeared or would occur only occasionally. It is in this way that the special fermentations develop.

If milk shows a peculiar flavor when it is first drawn it is safe to say that the flavor is not produced by bacteria, but by the cow, usually through something in the feed. If, on the other hand, the fresh milk is normal and the flavor develops as the milk stands, it is usually due to bacteria.

SOURING OF MILK.

Many of the lower plants find sugar a suitable food. In making use of this food, the sugar is chemically changed and in its place we find many new chemical compounds differing widely from the sugar from which they originated. Some bacteria in this process form various kinds of acids and gases. Among these is a large group of closely related bacteria which cause the souring of milk by breaking up the milk sugar into lactic acid. On account of this peculiarity they are commonly called the lactic-acid bacteria (fig. 5). Typical lactic-acid bacteria do not form gas. They do not have spores and therefore are destroyed at a comparatively low temperature. They are extremely widely distributed, and it is only under exceptional conditions that milk is obtained entirely free from them. They seldom or never occur in the udder itself, but probably are introduced into the milk with the hair, bits of feces, and dust that fall into the milk in the barn.

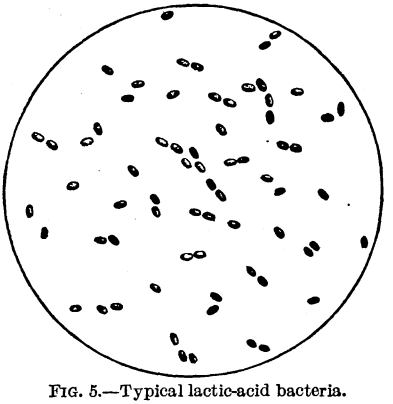

FIG. 5.—Typical lactic-acid bacteria.

Milk is an excellent medium for the growth of lactic-acid bacteria, and under favorable temperature conditions they multiply with astonishing rapidity.

The acidity of the milk is so closely connected with the life processes of this group of bacteria that it may be taken as a rough measure of their development. The acid, as fast as it is formed, unites chemically with the casein, which exists as very fine particles suspended in the milk serum. When the acid reaches a certain per cent, the acid casein is precipitated, and the milk is said to have "curdled" or "clabbered." This result may be hastened by heating. If milk or cream that is slightly sour is added to hot coffee, or is otherwise heated, it curdles.

Milk which has undergone a strictly lactic-acid fermentation has a firm curd, free from gas bubbles, and with a small amount of whey on the surface. When shaken the curd breaks up into small particles which settle slowly, leaving a clear whey. The milk should have a pleasant acid taste. So far as is known, none of the products of the bacteria of this group is of a poisonous nature.

Some of the bacteria sometimes classed with the lactic-acid bacteria form acids other than lactic, together with large quantities of gas. Milk curdled by bacteria of this class shows gas bubbles and has a disagreeable taste.

Not only are the lactic-acid bacteria able to grow in an acid medium, but to a certain point the acid is a favorable influence. Many bacteria, however, find the acid detrimental to their development and are not able to grow long in milk in competition with lactic-acid bacteria. When the milk begins to taste sour, the growth of nearly all nonacid-forming bacteria is checked. The activity of the lactic-acid bacteria themselves is checked and finally ceases entirely when the acid reaches a certain concentration, which varies with different varieties. Consequently sour milk usually contains a nearly pure culture of one or at most two or three closely related varieties of bacteria.

If a stoppered full bottle of ordinary raw milk is allowed to stand in a warm room for several days it usually develops a very sharp acid taste and frequently a somewhat slimy condition. This is due to the growth of a group of bacteria which occurs normally in milk but in small numbers only and which develop when certain favorable conditions are provided. They sometimes produce two or three times as much acid as the ordinary lactic-acid bacteria. In Turkey and neighboring countries milk fermented with these bacteria is a common article of food. In recent years the public has become familiar with these bacteria under the name of *Bacillus bulgaricus* or the Metchnikoff bacillus.

While the lactic-acid bacteria are considered very beneficial in butter and cheese making, they are undesirable bacteria from the standpoint of the milk dealer or consumer. It is almost out of the question absolutely to prevent their presence in milk, but the initial number may be much reduced by observing a few simple rules of cleanliness in handling the milk. Every precaution which reduces the amount of dirt in milk reduces the number of bacteria correspondingly. The important factors here are freedom from dust at time of milking, brushing the cows, wiping the udders, and small-mouthed milk pails. It is also of great importance to cool the milk as soon as possible after milking to below the temperature at which lactic-acid bacteria grow rapidly. This temperature is controlled by

practical conditions, such as the temperature of the water available for cooling, but it should not be higher than 50° F.

SWEET CURDLING AND DIGESTION.

It sometimes happens that milk curdles without showing the usual acid taste. This is followed by the separation of a straw-colored whey, which slowly increases until the curd has nearly all disappeared. This condition is the result of a series of complicated changes brought about by bacteria.

When milk is taken into the stomach, especially the stomachs of young animals whose diet is largely or wholly milk, a certain constituent of the digestive juice precipitates the casein, forming a firm curd. This curd resembles the acid curd in appearance, but differs from it chemically and has no sour taste. The part of the digestive juice which produces this change is the rennet, with which we are familiar in cheese making and in the junket tablets of the kitchen. It is what is technically known as an enzym, and while it has some of the properties which we ordinarily attribute to living beings, its action is purely chemical.

In this precipitated condition the casein is not in a form to be used by the animal. It must be so changed that it will go into a solution and pass through the membranes lining the digestive tract. This change is brought about by another enzym, pepsin. Pepsin changes the curd rapidly and completely into compounds soluble in water.

A process similar to these digestive processes in the stomach takes place in milk when it is subjected to the action of certain kinds of bacteria. The bacteria have no stomachs, but some of them have the ability to secrete enzymes somewhat like the rennet and the pepsin of animals. Thus the milk can or bottle becomes in a certain sense the communistic stomach of myriads of bacteria. From each cell is given out a trace of rennet and the digesting enzym. These enzyms have the peculiar property of acting continuously without reduction of their power. Thus it happens that the milk is curdled in a few hours and the casein is slowly converted into products capable of passing through the delicate membrane surrounding the bacteria. The food thus produced is obviously far in excess of the needs of the bacteria.

A large group of bacteria, more or less closely related, produce changes of this nature. Some of them form by-products with disagreeable odors and tastes and some form gases. They are found normally in the soil, in water, in the filth of the stable, or the dust that floats in the air. They are invariably found in milk in greater or less numbers. They are ordinarily checked by the activities of the lactic-acid bacteria and become predominant only under special conditions. When, through careless handling, any exceptional num-

ber of bacteria of this class are introduced into the milk, they may bring about rennet curdling and digestion before they are suppressed by the acid produced by the lactic-acid bacteria.

Again, in hot weather the temperature of the milk may be so high that it is more favorable to the digesting bacteria than to the lactic-acid bacteria and the former gain the ascendency.

BITTER MILK.

The distinct bitter taste which sometimes appears in milk may be caused by (1) certain weeds that the cow has eaten, (2) an abnormal condition of the udder, (3) an advanced period of lactation, or (4) the action of certain bacteria. The first three causes of bitter milk need not be discussed in this paper. It is probable that the bacteria causing bitterness are not at all uncommon and that they could be found in many lots of milk showing no bitterness. Some of these bacteria form acid and sour the milk; the more common forms, however, form little acid, and are checked by the growth of the lactic-acid bacteria.

Many of these form spores and thus survive heating which destroys a large part of the vegetative bacteria and thus changes the normal bacterial balance. For this reason bitterness has been most frequently observed in milk pasteurized at too high a temperature, imperfectly sterilized milk, or milk collected under conditions that exclude the greater part of the lactic-acid bacteria.

The bacteria causing bitterness in unheated milk are more frequently those of the acid-forming classes, which are better able to compete with the lactic-acid bacteria. The acid formed by this group is usually butyric and not lactic. Some writers have stated that the bitterness is caused directly by the butyric acid. Nearly all of the bateria known to produce bitterness bring about an active digestion of the casein and albumen, and it is probable that the bitter principle is formed in this decomposition. In most cases, however, the bitterness becomes evident before there is any visible sign of change in the milk.

Bitter milk may occur as an epidemic, persisting day after day and causing great trouble. This may be due to some constant localized source of infection which adds each day unusual numbers of bacteria to the milk. In some cases it has been found that the udder of a cow was infected. This should be determined by carefully cleaning the udders of all the cows and milking from each quarter of the udder of each cow into fruit jars or bottles which have been previously cleaned with boiling water.

In case one of these samples shows a well-developed bitterness while others remain normal, it may be assumed that the source of infection

is the udder of the cow giving this milk. In that case there should be injected into the udder after each milking a solution of 1 part hyposulphite of soda in 100 parts of water.

It is probable in many cases that the source of infection is not localized. If through some combination of circumstances the lactic-acid bacteria are suppressed, other kinds become predominant. The utensils, the milk room, and the stable gradually become inoculated with these bacteria or their spores and each new lot of milk is thoroughly inoculated. The bitter-milk bacteria may be one of the new forms. In this event it may be necessary, after thoroughly cleaning and steaming everything coming in contact with the milk, to introduce some good sour milk from a neighboring dairy. In this way the normal fermentation may be restored and the objectionable bacteria suppressed.

ROPY OR STRINGY MILK.

In this most troublesome fermentation the milk becomes what is commonly described as ropy or stringy. The milk is slimy and viscid. As this condition increases the milk may be drawn out into threads.

This fermentation should not be confused with garget, which appears in the fresh milk and is due to an inflammation of the udder. Ropy or stringy milk develops after the milk is drawn and is caused by the growth of certain kinds of bacteria. Although a number of kinds of bacteria causing this trouble have been studied as distinct varieties, it is probable that they are nearly all closely related. They do not form spores and are therefore destroyed by a comparatively low heat.

If a sample of ropy milk is examined under a microscope it is found to be filled with these small bacteria, each one surrounded by a capsule of a sticky, gummy substance. This gum or slime holds the bacteria together. When a thread is drawn out it is really a chain of bacteria held together by their sticky capsules.

Ropy milk is, so far as known, in no way detrimental to health. The famous Edam cheeses are nearly all made from milk which has undergone this fermentation. The peasants of Norway consider ropy milk a desirable beverage and bring about this fermentation by adding to fresh milk the leaves of certain plants on which the bacteria causing ropy milk are abundant. Most people, however, object seriously to milk with any tendency to form threads. This trouble frequently affects the milk of a dairy day after day and is removed only by the most drastic measures.

Outbreaks of this nature frequently occur in the cold months, because the bacteria of this group thrive better at low temperatures than the lactic-acid bacteria which hold them in check under normal conditions. In one case it was found that these bacteria were

abundant in the dust of the stable. The trouble was removed by a thorough cleaning and whitewashing. In another serious and persistent outbreak it was found that the milk as it came from the dairy contained few or no ropy milk bacteria, but that they were abundant in the water tank in which the milk was held over night. The small amount of water occasionally splashed into the cans added sufficient bacteria to make the milk ropy in a comparatively short time. The utensils and floor had become so thoroughly impregnated with this organism that milk exposed in the room or strained through the wire strainer became ropy without contamination with the water. The trouble was removed by thoroughly scalding all the utensils, disinfecting the floor with a 5 per cent sulphuric-acid solution, and destroying the organisms in the ice water by adding potassium bichromate. This was used in the proportion of 1 part in 1,000 or, roughly, 1 ounce to 1 cubic foot of water.

The source of the trouble can sometimes be easily located by taking small samples of the milk in clean glass jars at different stages in the handling. These should be covered, set away in a cool place to retard the souring, and examined after 24 to 36 hours for indications of ropiness.

In dairies getting milk from a number of farms the source of the difficulty may be located on some particular farm and proper methods taken to remove the source of contamination.

Any precaution is almost sure to be ineffectual if all utensils coming in contact with the milk are not thoroughly scalded, or, better still, steamed.

MISCELLANEOUS FERMENTATIONS.

In addition to the various fermentations previously described, milk may undergo many other changes as a result of the action of bacteria or other micro-organisms. The color may be changed. The appearance of color in milk is due to the growth of bacteria which produce a pigment soluble in water. All the colors of the rainbow, from bright red to violet, are formed by bacteria. Blue milk, which is the most common of the color fermentations, is probably due to contaminations from water, in which the blue and violet forming bacteria are known to occur frequently. It is only under unusual circumstances that these bacteria occur in milk in sufficient numbers to give any trouble.

Milk sometimes undergoes an alcoholic fermentation, and in some countries this is brought about by proper inoculation and control of temperature to produce a beverage. The alcoholic fermentation is usually caused by a yeast which has the ability to break up milk sugar into alcohol and large quantities of carbon dioxid gas. The ordinary

yeast, such as is used in bread making, produces similar changes in cane sugar, but does not affect milk sugar. In the alcoholic drinks made from milk the alcoholic fermentation is usually combined with an acid fermentation. Koumiss, a drink made originally in the Caucasus from mare's milk, is a combination of an alcoholic and a lactic-acid fermentation. This drink is believed to be beneficial in some diseases of the stomach and is frequently made from cow's milk. When made in this way with ordinary yeast it is necessary to add cane sugar.

Yoghurt, matzoon, or leben is a sour milk prepared in Turkey and neighboring countries with the so-called Metchnikoff bacillus to which reference has already been made. These various fermented milks are treated in more detail in Bureau of Animal Industry Circular 171.

DISEASE-PRODUCING BACTERIA IN MILK.

It is now generally recognized that many of the diseases which may be communicated from one person to another are caused by specific bacteria. The organisms causing some of these diseases have not yet been discovered, but the causal bacteria of many have been isolated and studied in detail. Some of these diseases occur usually only in human beings, others occur usually in animals and are only occasionally transmitted to men, while others may occur with equal frequency in both man and animals.

It is well known that certain diseases are sometimes disseminated through milk. By this means an epidemic may appear suddenly and last for a comparatively short time, or the infection may be continued for a long period and the development of the disease be so slow and obscure that the source is unknown.

Tuberculosis is an example of the latter class. So much in regard to this disease is still unknown, so many widely separated views are held, even by those most familiar with the subject, that it is impossible to make positive statements. However, tuberculosis has been studied in such detail that many facts have been well established, and many theories advanced are so probable that they can not be disregarded until they are disproved.

The question of the identity of tuberculosis of man with that of animals has been raised, and while it is not yet accepted as a fact by all investigators, a large majority of the people whose opinion has weight believe that the two diseases are identical. Assuming that they are, much difference of opinion exists as to the possibility of transmission from cows to man through milk. It is well known that other animals, including calves and pigs, may be infected by drinking milk from tuberculous cows, and the possibility that man, and especially children, may become infected in this way is so great that

to disregard it on the ground that it is still unproved is carelessness approaching criminal negligence. The tendency among those who are studying the question most carefully is to consider milk as a serious source of danger.

A number of epidemics of diphtheria and scarlet fever have been traced to the milk supply. In diseases of this nature the milk is infected by some one suffering from an attack of the disease, or through some one who has been in contact with the patient. Obviously no one suffering from a contagious disease, or one who is caring for a diseased person, should be allowed to go near the stables or milk room or handle milk utensils. The only really safe way is to enforce strict quarantine against farms where contagious diseases are known to exist.

Typhoid fever, while not as contagious as some other diseases, is readily communicated from one person to another. The ordinary channel of communication is generally considered to be the drinking water, which may be contaminated by sewage, but occasionally it is disseminated through the food. Milk may become infected with this disease in various ways. Contaminated well or spring water may find its way into the milk through milk pails, cans, or bottles which were not thoroughly scalded after rinsing in cold water; the cans or bottles of milk may be left to cool in contaminated water and become inoculated by the accidental addition of even a few drops of water; the cows may wade in water or mud containing the typhoid bacillus and the small drops of muddy water which dry on the animal's flank may carry the organism to the milk; or flies may go directly from the waste from the sick room to the milk or milk utensils.

It has been demonstrated in the last few years that certain people may carry and give off from their bodies virulent disease-producing bacteria, even though they may be in good health. This is especially true of typhoid fever, and there is no doubt that dairymen have in many instances been the cause of serious epidemics without any outward evidence that they harbored the bacteria of the disease. Diphtheria and affections of the throat are also known to have been disseminated in this way.

In this connection must be considered the summer intestinal diseases of children. While the specific bacteria causing these troubles have not been recognized, it is generally accepted that they are carried by the milk and that this is the important factor in their control. It is evident that they are closely associated with the use of milk which contains large numbers of bacteria. It is reasonable to suppose that by the continued use of poor milk many of these bacteria lodge in the intestines and there produce substances of a toxic nature. It has been proved by careful observation and

statistics that the death rate among babies in the crowded cities can be materially lessened by supplying them with good milk.

THE HANDLING AND CARE OF MILK.

Preventing changes in milk is a question of preventing the introduction of bacteria into milk and of checking their growth or destroying them when they are present. The production of milk reasonably free from bacteria is a simple question of cleanliness.

How far a milk producer can go in this direction with profit is a question that each one must decide for himself. The model dairies which are used as examples of what dairymen should do are frequently maintained in such an expensive manner that the farmer or dairyman doing a small business or producing milk in connection with other lines of farming can not expect to live up to their standards without increasing the cost of his milk.

However, there are many simple rules and methods for handling milk, requiring little extra labor and no added expense, which will materially increase the healthfulness and keeping quality of the product. Any precaution that reduces the dust in the stable at milking time reduces the initial number of bacteria in the milk. The cows should not be fed before milking. Cobwebs and other dirt can be easily removed from the ceiling. The stable floor should be so arranged that the dirt on the flanks and udders of the cows will be reduced to a minimum. The daily use of a brush will add greatly to the efficiency of these precautions. Care should be taken that the cows do not have to wade through filth in the barnyard.

Even with the greatest precaution some bacteria get into the milk, and further precautions must be taken to prevent their undue multiplication. The practical way to accomplish this is by control of the temperature of the milk. Advantage is taken of the natural law governing the limits and rapidity of growth of bacteria at different temperatures. The milk should be cooled at once to a temperature as near the freezing point as circumstances will permit. The usual limit is 50° F., but 40° F. is much more desirable.

The quickest and most economical method is to run the milk in a thin layer over the surface of a receptacle containing cold water. Many varieties of coolers for this purpose are on the market. Some are so arranged that a stream of water passes through them, while in others the milk flows over a conical tank containing cold water. It is not improbable, however, that in many cases the benefit derived from the cooling is overcome by the contamination of the dust on the cooler and the absorption of oders from the room in which it is used. A cooler should be located in a clean, well-ventilated room and be protected from dust by an efficient covering.

On farms where water is supplied by a windmill it is very easy to arrange the water trough so that the water flows from the pump through a trough or tank in which the cans of milk may be set to cool. This is a slow method, but much better than nothing.

It is not sufficient merely to cool the fresh milk. To insure good results it must be kept cold until used. The housekeeper who leaves her bottles of milk in the sun or standing in a warm kitchen should not blame the milkman for sour milk.

Various attempts have been made to preserve milk by holding it above instead of below the temperature favorable to the growth of bacteria. Devices for this purpose are called thermophores. While the most favorable temperature for many bacteria is at or near 98° F., few grow well at temperatures a few degrees above this point, and at 110° to 120° ordinary forms will not grow at all.

Milk held in thermophores usually will not curdle or change appreciably for several days, but it has been shown that unusual kinds of bacteria are able to develop at these high temperatures and that the milk which has every appearance of being good may contain large numbers of bacteria whose action is unknown. There are now on the market various bottles so constructed that the walls are almost perfectly insulated and thus permit only a slow change in the temperature of the contents of the bottle. Some of these have been recommended for holding babies' milk at the proper temperature for feeding through the night or on journeys. Nothing could be more pernicious, as the following table shows. In securing the results shown in this table a bottle of ordinary milk of good quality was divided, one half warmed to 102° F. and the other cooled to 36° F. These were put in pint vacuum-jacketed bottles and held in a warm room.

Growth of bacteria in milk held at feeding temperature.

Age of milk.	Temperature.	Bacteria per cubic centimeter.
Cold milk:	°F.	
Fresh	37	23,900
4½ hours	43	35,000
7½ hours	44½	46,000
Warm milk:		
Fresh	102	23,900
4½ hours	95	1,420,000
7½ hours	93	27,000,000

The large number of bacteria in the warm milk even at the end of 4½ hours makes the milk unsafe for infants' food. These bottles serve a very useful purpose when it is necessary to carry an infant on a journey, but they should be used only to keep the milk cold. When this is done the milk should be cooled by holding in a mixture of ice and salt until ice begins to form in the milk.

The next table shows the increase in temperature and bacteria in two samples of milk, one of which was properly cooled, while the other was only a little below the temperature of a good ice box. These two samples were held in pint vacuum-jacketed bottles and examined at the end of 24 and 48 hours:

Growth of bacteria in milk at low temperatures.

Age of milk.	Temperature.	Bacteria per cubic centimeter.
Inadequately cooled:	°F.	
Fresh	46.4	49,000
24 hours	64.4	2,140,000
48 hours	75.2	.....
Thoroughly cooled:		
Fresh	23.0	29,000
24 hours	37.4	36,000
48 hours	57.2	124,000

The milk that was inadequately cooled was long past the limit of safety at 24 hours, while the thoroughly cooled milk was still in good condition, bacteriologically, after 48 hours.

Chemicals having an injurious effect on bacteria are sometimes used to retard the growth of bacteria in milk and thus prolong the time within which it may be sold. This practice is so universally condemned by public opinion that it need not be discussed here.

Heat is frequently applied to milk to destroy a part or all of the bacteria. Complete destruction of all bacteria in any substance is sterilization; pasteurization is a term used to designate a process of heating by which milk or other fluids are heated to destroy part, but not all, of the bacteria. Pasteurizaton may be by the "flash" method in which the milk, flowing in a continuous stream, is heated and cooled very quickly, or the "holder" process in which the milk after being heated is held or retarded so that the temperature is maintained 20 or 30 minutes.

The temperature of pasteurization, as it is ordinarily practiced, varies greatly. As a general rule, to insure good results, the temperature must be increased as the length of exposure is decreased.

When the milk is held 20 to 30 minutes the best temperature is 145° F. This is safely above the point at which the bacillus of tuberculosis is destroyed and below the temperature at which changes take place in the milk. Pasteurization at this temperature does not destroy all of the lactic-acid bacteria; consequently the milk will become sour before other bacteria have produced undesirable changes.

In the continuous machines, where the milk is maintained at the pasteurizing temperature usually for only 25 or 30 seconds, the temperatures used range from 160° F. to 185° F. The results at 160° F. are uncertain, and any temperature below this point has little or no beneficial effect. Milk may be efficiently pasteurized in the household by setting the bottle of milk in a vessel containing water,

and heating the water until the milk reaches a temperature of about 145°. The bottle should then be taken from the water, wrapped in a towel and held 20 to 30 minutes. It should be then chilled at once and kept cold until used. Milk should in all cases be used within 24 hours after delivery.

Pasteurization should not be confused with sterilization. Even when the former is efficiently done many bacteria survive the heating and the milk must be properly cared for until it is used.

Milk may be sterilized by repeated boilings. This is usually accomplished by steaming on three or four successive days. After each boiling it should be held at room temperature for 24 hours to allow the spores to germinate and reach the vegetative stage. However, this method is by no means certain, especially if the milk contains a large number of bacteria, and to insure sterilization it is necessary to expose it to a temperature above the boiling point, which may be done in one operation by holding it in a closed chamber with steam under pressure.

Milk can also be sterilized by chemical means. The so-called "Buddeized" milk is sterilized by adding a small amount of hydrogen peroxid, which acts energetically on bacteria and is itself slowly decomposed into two harmless substances, oxygen and water. Milk treated in this way is said to be not entirely free from an objectionable taste and the sterilization is not always certain.

While bacteria are in no way essential to milk, they may be considered as normally present in milk, cream, ice cream, butter, and cheese. They may even occur in milk or its products in very large numbers without making it an unsafe food or in any way decreasing its food value.

Bacteria known to produce disease are seldom isolated from or counted in milk, and bacteriological counts should be taken merely as an indication of the way in which milk has been collected or the temperature at which it has been held. High numbers usually indicate insanitary conditions, careless handling, or old milk. However, milk may be collected under very poor conditions and the bacterial count held down by a liberal use of ice. On the other hand, milk collected in the most sanitary manner may in a few hours contain a large number of bacteria if it is held at a high temperature. Low counts may be due not to clean stables, and low temperatures, but to the use of antiseptics.

Every effort should be made by legitimate means to secure milk with a small number of bacteria, but milk or foods made from milk should not be indiscriminately condemned because they sometimes contain bacteria in numbers which are startling to those not familiar with the nature of these indispensable plants.

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